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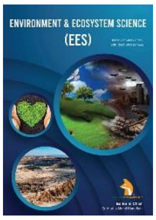

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RESEARCH ARTICLE

RISK ASSESSMENT OF SOIL ORGANIC POLLUTANTS SURVEY AT A CERTAIN OIL DEPOT SITE IN GUANGZHOU

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ABSTRACT

In order to investigate the pollution situation of the relocation site of an oil depot in Guangzhou, based on the health risk assessment theory, the investigation and monitoring of soil and groundwater organic pollutants in the site was conducted, and the health risk assessment was carried out combined with the monitoring data.24 types of pollution factors, including 1,3,5-trimethyl benzene, were detected and the maximum concentration accounted for 67% of the screening value; toluene and extractable petroleum hydrocarbon (C10-C40) were detected in the plot, and the maximum concentration accounted for 1%~2% of the screening value. The results show that the maximum risk area of the legacy site is the oil depot area, with soil and groundwater organic matter; the maximum concentration of organic pollutants in the site ($\leq 10^{-6}$)Or non-carcinogenic hazard entropy (≤1), and the future exposure receptor is not affected by the health risk of the soil and groundwater organic pollutants in the site.

KEYWORDS

Soil, groundwater, organic pollution factor, health risk assessment, screening value

1. INTRODUCTION

In recent years, the domestic urbanization speed is fast, and the urban scale is gradually expanded, and a large number of non-urban population enters the urban circle, which makes the urban land more precious. In order to solve the shortage of land for human settlements, local governments have accelerated the centralized management of key sewage discharge enterprises in the industrial parks. During the industrial production process of sewage disposal enterprises, the soil of the site may be polluted. Especially after the relocation of the enterprises, a large amount of seriously polluted land is left in the urban area. Without monitoring and assessment, the failure to dispose of the large amount of contaminants remaining on the plot will inevitably have a long-term impact on the construction land that becomes human habitation or activity. In the western developed countries, the research on health risk assessment of contaminated sites has been carried out earlier, and it is at a high level. For example, in 1994, the Netherlands developed a technical approach to health risk assessment and established a baseline value for soil contamination for the purpose of protecting human health (Swartjes, 2007).

In 1998, the Risk-Based Corrective Action (RBCA) model for site risk assessment was proposed in the United States (U.S.EPA,2009). And the *Regional Soil Screening Values* based on human health have also been developed, and the soil screening values have been used for different functional land use as reference technical approach. The RBCA model has been referenced by all countries in the world (U.S.EPA, 1996; Colin, 1999; Joop, 2001; Christie, 1998). A technical approach to health risk assessment of contaminated land was published in the UK in 2002 and revised again in 2009. At present, the UK has established a complete health risk assessment framework for contaminated sites (Pollard et a1.,2002). In recent years, China has also referred to the RBCA model as health risk assessment. Since 1980s, it mainly focused on water environment at the beginning (Ji et a1., 2010; Hu et a1.,2010; Hu et a1., 2011; Li et a1., 2011; Zhu et a1.,2010).

As soil and atmospheric environment are paid more and more attention, relevant risk assessment research has been increasing. For example, soil researchers conducted health risk assessment studies on residual pesticides and organic substances in soil, and some conducted health risk assessment studies on residual heavy metals in contaminated soil (Feng et a1.,2011; Liang et a1.,2020; Dong et a1.,2016; Wang et a1.,2016; Peng et a1.,2020; Wang et a1.,2018; Xu et a1., 2020; Wang et a1., 2020). Therefore, the soil and underground water contamination investigation and risk assessment of construction land is of great significance to the sites that may be polluted. Based on the theory of health risk assessment, this study adopts the scientific, reliable and highly recognized health risk assessment model method to investigate and evaluate the contamination and health risk of an oil depot in Guangzhou. And this provides a scientific basis for contamination control of similar sites.

2. MATERIALS AND METHODS

2.1 Site Background

The oil depot was built in 1970. Before construction, the site is farmland. After the completion of the oil depot, it was used as an aviation fuel refueling terminal. The area of the right of use of the plot is 30,116.23m², and the land nature is industrial land. In the 90s, the project requisitioned the vegetable plot on the west side of the plot, and the oil depot was

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renovated and expanded. New vertical tank farm and other supporting facilities; At the beginning of 2000, the new oil depot was officially put into use, and the original horizontal tank was removed; The site mainly includes oil tank facilities, oil pumps, oil pump rooms, testing stands, sewage treatment stations, fire pools and fire pump rooms, hardware warehouses, office buildings, power distribution rooms, garages and dormitories. In 2008, due to business stagnation, the oil depot was deactivated, but the facilities remained and the plot was idle; After 2010, the oil tank facilities, oil pumps, oil pump rooms, testing stands, sewage treatment stations, fire pools and fire pump room facilities were demolished and replaced with temporary parking lots and has been put into use till today.

2.2 Site Monitoring Distribution

According to the requirements of *Technical Guidelines for Risk Control and Remediation Monitoring of Soil Contamination of Construction Land* (HJ 25.2-2019), 2 soil control points shall be set in the undisturbed area outside the oil depot. 19 soil investigation points were set in the site, and 105 soil samples were collected. The underground water monitoring well shall be set, and the installation depth of the monitoring well shall be 2m below the water level of the first aquifer at each sampling point. 5 underground water detection wells with numbers of W1~W5 are arranged in the upstream and downstream directions of underground water in the plot and in the center of the plot. See Figure 1 for each sampling point.

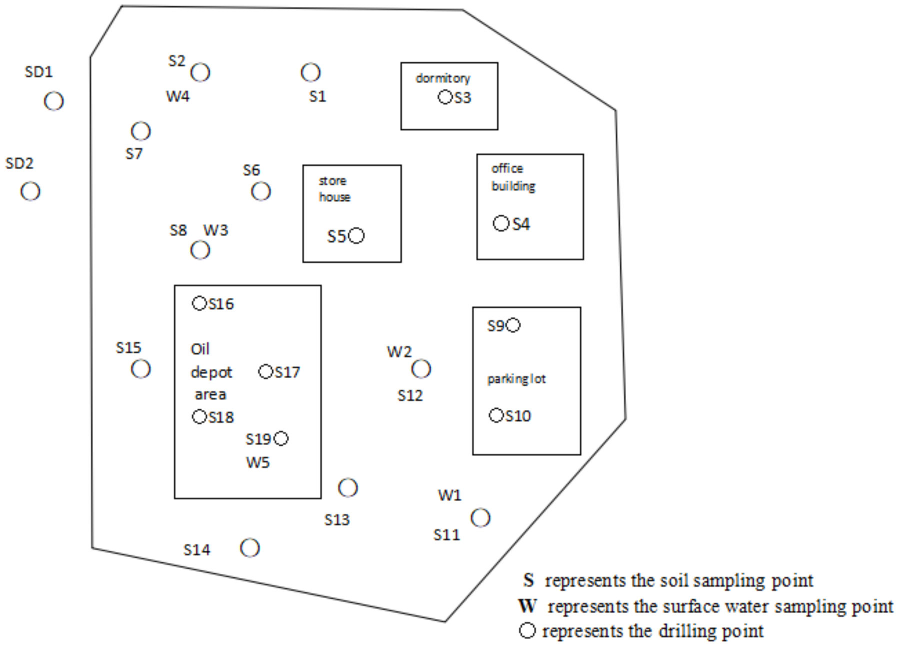

Figure 1: Location map of soil and groundwater monitoring sites

2.3 Analysis Method

Except that Guangzhou local technical specification DBJ440100/T75-2010 is adopted for semi-volatile organic compounds of underground water at the site, the currently effective national environmental protection standard (HJ) is adopted for the analysis method for monitoring indexes of other organic contaminants, as shown in Table 1.

Table 1: Analysis methods for organic pollutants

Analytic Procedure	surveillance project
Soil and Sediment-Determination of Volatile Organic Compounds -Purge and Trap Gas Chromatography/Mass Spectrometry Method HJ 605-2011 Water quality--Determination of Volatile Organic Compounds -Purge and Trap Gas Chromatography/Mass Spectrometry Method HJ 639-2012	volatile organic compounds
Soil and Sediment-Determination of semivolatile organic Compounds -Gas Chromatography/Mass Spectrometry Method HJ 834-2017 Water quality--Determination of semi-volatile organic pollutants (SVOCs) Liquid-liquid extraction-gas chromatography / MS analysis DB J 440100/T 75-2010	Semi-volatile organic compounds
Soil and Sediment-Measurement of petroleum hydrocarbon (C10-C40) by gas chromatography HJ 1021-2019 Water quality--Determination of extractable petroleum hydrocarbons (C10-C40) chromatography of gases HJ 894-2017	petroleum hydrocarbon (C10-C40)
Soil and sediment—Determination of polychlorinated biphenyls —Gas chromatography HJ 922-2017 Water quality--Determination of the PCBs gas chromatography-mass spectrometry HJ 715-2014	Seven indicative PCBs、12 co-planar PCBs
Water quality--Determination of the PAHs Liquid liquid extraction and solid phase extraction HPLC HJ 478-2009	Benzoid (b) fluoranthene Benzoid (b) pyrene

3. Results and Discussion

3.1 Analysis of test results

3.1.1 Soil Results Analysis

A total of 105 soil samples were collected in the plot, mainly including petroleum hydrocarbon (C10-C40), polychlorinated biphenyls (PCBs), volatile organic compounds (VOCs), semi-volatile organic contaminants (SVOCs), etc. Among the samples tested above, the following contaminants were detected: 2-methylnaphthalene, phenanthrene, anthracene, fluoranthene, pyrene, benzo (a) anthracene, heme, benzo (b) fluoranthene, benzo (k) fluoranthene, benzo (a) pyrene, indeno [1, 2, 3-cd] pyrene, benzo (g, h, i) perylene, toluene, ethylbenzene, m-xylene, o-xylene, cumene, n-propylbenzene, 1, 3, 5-trimethylbenzene, tert-butylbenzene, 1, 2, 4-trimethylbenzene, sec-butylbenzene, petroleum hydrocarbons (C10-C40), 24 items in total, See Table 2 for sample detection items and detection rate.

Table 2: Detection items and detection rates of organic pollutants in soil samples			
Check out the project	**Total number of samples (s)**	**Number of detected (s)**	**relevance ratio**
Semi-volatile organic compounds(SVOCs)			
2-Methylnaphthalene	105	16	15.2%
phenanthrene	105	8	7.6%
anthracene	105	2	1.9%
fluoranthene	105	2	1.9%
pyrene	105	5	4.8%
Benzoite (a) anthracene	105	1	0.95%
anthracene	105	10	9.5%
Benzoid (b) fluoranthene	105	2	1.9%
Benzoid (k) phenanthene	105	2	1.9%
Benzoid (b) pyrene	105	2	1.9%
Indene and [1,2,3-cd] pyrene	105	3	2.9%
Benzens (g, h, i)	105	2	1.9%
volatile organic compounds(VOCs)			
methylbenzene	105	10	9.5%
ethylbenzene	105	15	14.3%
m, p-xylene	105	50	47.6%
o-xylene	105	9	8.6%
cumol	105	15	14.3%
n-proplbenzene	105	22	20.9%
1,3,5-trimethylbenzene	105	11	10.5%
tert-butylbenzene	105	2	1.9%
1,2,4-trimethylbenzene	105	18	17.1%
Central butyl benzene	105	9	8.6%
petroleum hydrocarbon			
petroleum hydrocarbon (C10-C40)	105	98	93.3%

The detected items and results of soil samples in the site are basically consistent with the contamination identification indicators of the preliminary investigation of the plot. The detection types of organic matter in the plot also conformed to the composition identification law of kerosene by contamination identification, and the main detection types were benzene series, polycyclic aromatic hydrocarbons and petroleum hydrocarbons, but the corresponding concentrations were lower than the risk screening values of the first type of land.

3.1.2 Analysis of underground water results

One underground water sample was collected from each of the 5 monitoring wells in the plot for laboratory testing. The indicators of detected contaminants in underground water samples are extractable petroleum hydrocarbon (C10-C40) and toluene. See Table 3 for the detection data.

Table 3: Results of groundwater sample detection items (unit: mg/L)					
monitor well	**W1**	**W2**	**W3**	**W4**	**W5**
methylbenzene	ND	ND	0.005	ND	0.0085
Extractable petroleum hydrocarbons(C10-C40)	0.045	0.083	0.180	0.095	0.220

remarks: ND is not detected

3.2 Contamination Risk Screening Values

3.2.1 Soil Risk Screening Values

According to the requirements of *Notice on Technical Essentials of Site Environmental Investigation, Restoration and Effect Evaluation Documents of Guangzhou Industrial Enterprises* (HHB [2018] No. 173), the screening values of corresponding contaminants specified in the *Standard for Risk Control of Soil Contamination of Construction Land for Soil Environmental Quality* (Trial)(GB36600-2018) shall be preferentially selected. The characteristic contaminants not covered by these standards, refer to the local standard *Screening Value for Site Environmental Risk Assessment of Soil* (DB11T811-2011). As the matters in the soil including cumene, n-propylbenzene, 1,3,5-trimethylbenzene, tert-butylbenzene, 1,2,4-trimethylbenzene, sec-butylbenzene, 2-methylnaphthalene, anthracene, fluoranthene, pyrene and extractable petroleum hydrocarbon (C10-C40) in underground water, the soil contamination risk screening value of specific contaminant shall be deduced according to *Technical Guidelines for Soil Contamination Risk Assessment of Construction Land* (HJ25.3-2019).

Contaminants in soil and underground water that do not have relevant standards enter the risk assessment stage. Since there are two types of planning for the Class I and II types of construction land in the target plot, based on conservative considerations, the Class I type of construction land is strictly selected as the risk screening value. The screening values of some detected contaminant index are carried out by GB 36600-2018 standard. Since phenanthrene and benzo(g, h, i) beryl have no screening values in this standard, combined with the situation that park green space is involved in the plot planning, the screening value is performed with reference to the park and green space screening value in Beijing local standard DB11T811-2011. Other component detection metrics use derived values from the model. The screening values of soil detection items in this project are shown in Table 4.

Table 4: Screening values of soil detection items		
Detection of pollutants	**Screening Value(mg·kg^{-1})**	**Screening value basis**
methylbenzene	1200	Soil environmental quality risk control standard for soil contamination of development land GB 36600-2018 the first class of construction land limits
ethylbenzene	7.2	
m, p-xylene	163	
o-xylene	222	
cumol	546.61	Technical guidelines for risk assessment of soil contamination of land for construction HJ 25.3-2019 sensitive ground-derived values
n-proplbenzene	1267.33	
1,3,5-trimethylbenzene	83.11	
tert-butylbenzene	3303.77	
1,2,4-trimethylbenzene	105.97	
Central butyl benzene	3303.77	
2-Methylnaphthalene	146.12	Technical guidelines for risk assessment of soil contamination of land for construction HJ 25.3-2019 sensitive ground-derived values
phenanthrene	6	Screening levels for soil environmental risk assessment of sites DB11/T 811-2011 Park and green space screening value
anthracene	10959.49	Technical guidelines for risk assessment of soil contamination of land for construction HJ 25.3-2019 sensitive ground-derived values
fluoranthene	1461.26	
芘pyrene	1095.94	
Benzoite (a) anthracene	5.5	Soil environmental quality risk control standard for soil contamination of development land GB 36600-2018 the first class of construction land limits
anthracene	490	
Benzoid (b) fluoranthene	5.5	
Benzoid (k) phenanthene	55	
Benzoid (b) pyrene	0.55	
Indene and [1,2,3-cd] pyrene	5.5	
Benzens (g, h, i)	6	Screening levels for soil environmental risk assessment of sites DB11/T 811-2011 Park and green space screening value
petroleum hydrocarbon (C10-C40)	826	Soil environmental quality risk control standard for soil contamination of development land GB 36600-2018 the first class of construction land limits

3.2.2 Underground water Risk Screening Values

The contaminants detected in underground water are regarded as potential contaminants of concern, and the screening value of underground water environmental risk assessment is developed. According to the requirements of *Notice on Technical Essentials of Site Environmental Investigation, Restoration and Effect Evaluation Document of Guangzhou Industrial Enterprises* (HHB [2018] No. 173) and in combination with the underground water function zoning of the plot, Class IV standard in *Underground Water Quality Standard* (GB/T 14848) is adopted as the screening value. Contaminants not covered by relevant national and local standards, according to *Technical Guidelines for Risk Assessment of Soil Contamination of Construction Land* (HJ 25.3-2019), deducing a underground water contamination risk screening value for a specific contaminant, See Table 5 for the screening values of underground water detection indicators at the site.

Table 5: Screening values of groundwater detection indicators			
Order Number	**Detection index**	**Standard / Screening Values(mg·L^{-1})**	**source**
1	methylbenzene	1.4	Standard for groundwater quality GB/T 14848-2017
2	Extractable petroleum hydrocarbons(C10-C40)	0.572	Technical guidelines for monitoring during risk control and remediation of soil contamination of land for construction (HJ 25.3-2019)the derivation value

3.3 Health Risk Assessment

According to the calculation formula and model parameters of *Technical Guidelines for Risk Assessment of Soil Contamination of Construction Land* (HJ25.3-2019) in China, a preliminary site exposure conceptual model is established based on the deduction of risk screening value according to the actual situation of the plot. The sensitive groups including children and adults are considered. The exposure route is mainly caused by ingestion of soil by mouth, skin contact with soil, breathing in soil particulate matter, breathing and inhaling the volatilizes vapor of the polluted soil surface layer into or external the room, etc. The risk assessment software of *Contamination Site Risk Assessment Spreadsheet-2020-10-09* developed by Nanjing Soil Institute was used to participate in the calculation to obtain the health risk values of organic contaminants in the soil and underground water in the site. See Table 6 and Table 7 for specific data.

Table 6: Maxvalues of soil samples and their health risks

Check out the project	Monitoring point and depth(m)	potency crest value	Screening value ($mg\cdot kg^{-1}$)	Number of samples with excess risk screening value	Cancer risk	Non-carcinogenic Dangerous entropy	risk controlling value ($mg\cdot kg^{-1}$)
Volatile organic compounds (VOCs)($mg\cdot kg^{-1}$)							
methylbenzene	S16 6.7~7.0	0.899	1200	0	——	3.42E-04	1.60E+03
ethylbenzene		0.069	7.2	0	1.12E-09	2.12E-05	5.73E+00
m, p-xylene		0.533	570	0	——	1.67E-05	1.59E+01
o-xylene		0.541	640	0	——	1.70E-05	1.07E+03
cumol		1.523	2895	0	——	4.99E-04	5.47E+02
n-proplbenzene	S17 5.7~6.2	2. 952	7415	0	——	9.23E-04	1.27E+03
1,3,5-trimethylbenzene	S17 4.8~5.0	0.388	456	0	——	3.67E-04	2.57E+02
tert-butylbenzene		0.0653	29775	0	——	1.98E-05	3.30E+03
1,2,4-trimethylbenzene		5.856	587	0	——	5.54E-03	3.30E+02
Central butyl benzene		0.455	29775	0	——	1.38E-05	3.30E+03
Semi-volatile organic compounds (SVOCs)($mg\cdot kg^{-1}$)							
2-Methylnaphthalene	S16 6.7~7.0	2.63	1010	0	——	6.84E-04	1.46E+02
phenanthrene		0.5	-	-	——	4.71E-04	1.06E+03
anthracene		0.2	75782	0	——	1.82E-05	1.10E+04
fluoranthene		0.5	10104	0	——	3.42E-04	1.46E+03
pyrene		0.2	7578	0	——	1.82E-04	1.10E+03
Benzoite (a) anthracene	S16 4.8~5.2	0.1	15	0	1.83E-08	——	5.46E+00
anthracene		0.4	1293	0	7.33E-10	——	5.46E+02
Benzoid (b) fluoranthene		0.3	15	0	3.66E-09	——	5.47E+00
Benzoid (k) phenanthene		0.2	151	0	3.66E-08	——	5.47E+01
Benzoid (b) pyrene		0.1	0.55	0	1.83E-07	2.13E-02	5.47E-01
Indene and [1,2,3-cd] pyrene	S18 5.8~6.1	0.2	15	0	3.66E-08	——	5.47E+02
Benzens (g, h, i)		0.1	6	——	——	——	——
petroleum hydrocarbon ($mg\cdot kg^{-1}$)							
petroleum hydrocarbon (C10-C40)	S17 4.8~5.0	555	826	0	——	6.72E-01	8.26E+02

The above results indicate that the organic contaminants are detected in the soil mainly concentrated in the storage area of the oil depot, and are not detected or at the lower limit for the remaining office areas, dormitories and warehouses, which may be related to the volatile leakage during the normal loading and unloading operation of the oil reservoir area or during the cleaning of the oil tank at that time. According to the maximum concentration ratio analysis, benzo (a) pyrene and petroleum hydrocarbon (C10-C40) are prominent, accounting for 18% and 67% of the screening values of Class I respectively, and the rest are not more than 1%-2% of the screening values of Class I, which is basically consistent with the characteristics of kerosene components stored in the oil tank area at that time, but the maximum concentration of all detected indicators is lower than the screening values. At the same time, the risk characterization of the detected organic contaminant factors does not exceed the total carcinogenic risk of a single contaminant 10^{-6} or non-carcinogenic hazard entropy 1. On the basis of risk characterization, the risk control value of each detected indicator is judged and calculated, and the risk control value does not exceed the acceptable risk level. Therefore, the risk of organic contaminants in the plot is within the acceptable range.

Table 7: Maximum detection items of ground water and its health risks (Unit: $mg\cdot L^{-1}$)

Check out the project	**Maximum concentration W5**	**IV Class criteria / screening values**	**Cancer risk**	**Non-oncogenic hazard entropy**	**Risk control value**
methylbenzene	0.0085	1.4	——	——	1.90E+03
Extractable petroleum hydrocarbons(C10-C40)	0.22	1.8	——	——	——

Toluene and extractable petroleum hydrocarbons (C10-C40) were detected in groundwater at the site, but their maximum concentrations were lower than the Class IV standards in the Underground water Quality Standard (GB/T 14848-2017) and the Technical Guidelines for Risk Assessment of Soil Contamination of Construction Land (HJ 25.3-2019), and the pollution risk was also within the acceptable range.

4. Conclusion

According to the potential concern contaminants and potential concern areas determined by contamination identification, 19 soil sampling points are arranged in the site, 105 soil samples are collected and 5 underground water samples are collected. After testing and analysis, a total of 24 kinds of organic pollutants were detected in this site, including 11 VOCs substances and 12 SVOCs substances. The main detected products include benzene series, polycyclic aromatic hydrocarbons and petroleum hydrocarbons, among which petroleum hydrocarbons (C10-C40) are more obvious. By analyzing the spatial distribution characteristics of the plot and comparing with the relevant evaluation standards, the soil contaminants are mainly concentrated in the oil depot storage area. However, the rest office areas, dormitories and warehouses are not detected or at the lower limit of detection.

Among the soil and underground water detection indicators, benzo (a) pyrene and petroleum hydrocarbon (C10-C40) were prominent, accounting for 18% and 67% of the screening value, respectively. The rest did not exceed 1%~2% of the screening value of Class I, but all the detection indicators were lower than the screening value. Health risk assessment analysis showed that the risk characterization of the detected organic contaminant factors does not exceed the total carcinogenic risk of a single contaminant 10^{-6} or non-carcinogenic hazard entropy 1.On the basis of risk characterization, the risk control value of each detected indicator is judged and calculated, and the risk control value does not exceed the acceptable risk level. Therefore, soil and underground water organic contaminants in the site do not pose a health risk to future exposed receptors.

There are some deficiencies in the site soil contaminant risk assessment research process. The impact of the site organic contaminants on the living residents around or surrounding environment is not taken into account. In the future, it is suggested to collect relevant surrounding environment and underground water hydrological information during site survey, and make a detailed monitoring and distribution scheme to facilitate the comprehensiveness of the investigation, to improve the trend of site soil investigation and underground water organic contamination.

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